DOCUMENT RESUME

ED 296 697 IR 013 269

AUTHOR Collis, Betty A.; And Others
TITLE A Manifold Model of Computer Access and Interaction for Secondary School Males and Females.
PUB DATE Apr 88
NOTE 98p.; Paper presented at the Annual Meeting of the American Educational Research Association (New Orleans, LA, April 5-9, 1988).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC04 Plus Postage.
DESCRIPTORS Adolescents; *Equal Education; Foreign Countries; Goodness of Fit; *Mathematical Models; *Microcomputers; Secondary Education; *Sex Differences; Use Studies
IDENTIFIERS Canada

ABSTRACT

Based on the concept of a mathematical manifold, the model developed for this study was designed to measure and provide insights into the interaction of gender and access to computers among Canadian adolescents, as well as the multiple situational and personal variables which can constrain or facilitate computer access for the adolescent. The model was tested on data gathered by questionnaire from 2,818 Canadian 11th grade students representing urban areas in all 10 Canadian provinces. The general manifold model was adapted to predict access in three different usage categories--recreational use, nonrecreational home use, and school use--and each of these adaptations was tested on the male and female data separately. Subsequent adaptations of the model to reflect hypotheses about gender differences in access patterns were also tested with the male and female data. The full models and the male and female models provided reasonable to strong fits for the data. These results offer insights into patterns of computer use by adolescents and support the viability of the manifold model as a theoretical framework for further research. Data tables and diagrams of the models are appended. (25 references) (Author/MES)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED296697

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
This document has been reproduced as received from the person or organization originating it.
Minor changes have been made to improve reproduction quality.
Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

A Manifold Model of Computer Access and Interaction for Secondary School Males and Females

Betty A. Collis

University of Victoria

Thomas E. Kieren and Heidi Kass

University of Alberta

Running head: MANIFOLD MODEL

Betty A. Collis is an Associate Professor in the Department of Psychological Foundations, University of Victoria, Victoria, British Columbia. She specializes in computer applications in education, statistics, and research design.

Thomas E. Kieren is a Professor in the Department of Secondary Education, University of Alberta, Edmonton, Alberta, where he specializes in mathematics education.

Heidi Kass is a Professor in the Department of Secondary Education at the University of Alberta, Edmonton, Alberta, where she specializes in science education.

IR013369

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

Betty Collis

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

Abstract

Any attempt to understand and measure the interaction of gender and access to computers among Canadian adolescents needs to be mediated through the type of usage associated with the access and should also reflect the multiple situational and personal variables which can constrain or facilitate computer access for the adolescent. A model, based on the concept of a mathematical manifold, was developed to reflect this type of multivariate interaction and was tested on data from 2,818 Canadian Grade 11 students representing urban areas in all ten Canadian provinces. The general manifold model was adapted to predict access in three different usage categories--recreational use, nonrecreational home use, and school use--and each of these adaptations was tested on the male and female data separately. Subsequent adaptations of the model to reflect hypotheses about gender differences in access patterns were also tested with the male and female data. The models provided reasonable to strong fits for the data with generalized R^2s ranging from .874 to .979 for the full models pertaining to nonrecreational home use and school use and from .820 to .939 for the male and female models adapted from these full models. These results provide insights into adolescents and patterns of computer use and more generally support the viability of the manifold model as a theoretical framework for further research.

013269

A Manifold Model of Computer Access and Interaction for Secondary School Males and Females

Studies to date on computer use in secondary schools provide an incomplete picture of student-computer relationships. For example, some of these attempt to express this relationship in terms of a single measurement. However, in assessing the impact of computers on adolescent youth and in trying to understand the manner in which young persons value computers for themselves, for society, and for their futures, such a single-number quantification would be an oversimplification. It could not express the multiple social and personal factors which can constrain or facilitate computer access for an adolescent (Paisley, 1985), nor can it reflect the changing social and cultural patterns which are accompanying computerization in our society and embed the adolescent's decision to interact with a school or home computer (Cordell, 1985; Nora & Minc, 1981; Pask & Curran, 1982). In addition, such studies frequently have failed to consider the type of computer use in which the adolescent-computer relationship is being considered. Idhe (1978) has noted that human-computer interaction is a function of the context of the computer use. For example, learning with a computer in school or at home is a different context than using a computer as a personal tool or for recreational purposes.

Data from various pilot administrations of a national study of the impact of microtechnology on Canadian youth over the period 1983-1987 revealed that over 30 per cent of adolescent students sampled indicated that they could access computers at home and that over 67 per cent indicated they had access in homes of acquaintances or relatives (Kass & Kieren, 1985, 1986). Such out-of-school uses, which appeared from the data to be quite varied, have implications for school and other formal educational programs. It seems indicated that out-of-school experiences and constraints on access to these experiences may have larger and certainly different impacts on the social values, stereotypes, and concerns about computers held by Canadian youth than may be the case for school experiences alone.

There are numerous dimensions upon which one could base a theory of human-computer interaction and its interpretation by the adolescent actors. Paisley (1985) sees demographic variables (including age, gender, school characteristics, SES, and parents' education), affective variables (beliefs about computers, evaluation, and self-esteem in their presence), social variables (peer and parent values), and context variables (institutional or individual group use), as well as cognitive and particular computer configuration variables as critical in describing computer access by youths and the effect of this access. Among

factors which influence computer access for secondary school students, Schubert (1984) lists policies, software selection, peer encouragement, and role of family and peers as critical.

In addition, an interpretive model of access to computers and its effects must also take a variety of other dimensions of computer interaction into consideration. These other dimensions include the values adolescents carry toward computer-related concepts and issues in their larger society. Also such a model should relate to the self-efficacy of young persons with respect to computers and to the relationships of this self-efficacy to present and future social and personal values and concerns.

The individual's degree of valuing of computers, his or her identification with computers and perceived competence in a computer society, and orientation toward related social issues and concerns are interrelated with the individual's feelings toward computers. Turkle (1984) suggests that such feelings are not general but are highly related to context. One common feeling manifesting itself in a variety of ways is intimidation or anxiety in the face of computer hardware and software and its use (Shore, 1985). Collis (1984, 1985) suggests such discomfort is more evident for young females than males. Such personal discomfort might be a factor in what Collis describes as "We can, but I can't" conceptualization of self-efficacy in the face of

computers. Such sex differences in feelings toward computers and related self-efficacy are likely a complex phenomenon, at least paralleling the well documented complexity of gender differences in attitude and participation in mathematics and science among adolescents (Ethington & Wolfle, 1986; Hattie & Fitzgerald, 1987). It seems likely that experiences in different computer environments will likely generate varying levels and feelings of competence, control, and frustration, and that these feelings may differ for adolescent males and females. A model of computer access and usage should reflect the potentially different nature of this access relative to gender.

Whatever the use form, critics have suggested that uses of computers, particularly at the level of a computerized, computer-accepting society, could be destructive of human relationships and potentially could degrade culture. Heidegger (1977) considers the enframement of society by technology as limiting society's vision, potential, and life. Persons may be too ready to trust the authority of computers (Shore, 1985) or to show unwarranted faith in computer power (Shallis, 1984). The social values which adolescent youth hold toward computers are likely to be interrelated with the nature of their access to computers and may be indicative of possible future problems with respect to technological "enframements." A useful model of

use/value relationships should allow for examination of the interrelationship between social values and concerns and personal access and interactions with computers.

Another enframement which may serve as a personal constraint in computer use and may also contribute to an improper valuing of computers in society relates to the stereotypes of computer use and users held by adolescents. Such stereotypes may have to do with the place of computers in society (work as opposed to personal) and the perceived future role of computers in a person's life. Sex differences (Collis, 1987; Ellis & Sayer, 1986; Lockheed & Frackt, 1984) in such stereotyping can arise and be personally enframing, particularly for females. A model of relationships between interaction and interpretation of computer use by Canadian youth should include held stereotypes as a variable constraining access and influencing values and concerns.

The 'Manifold Model' of Adolescent/Computer Access

In mathematics, the state of a dynamic system at any point in time is called a manifold. In analyzing the nature of the access that Canadian youth have to computers, we use this notion of a multifaceted manifold to characterize the interrelationships. Access, values, stereotypes, and social concerns of young persons about and towards computers, both personally and socially, and the

way in which this interrelationship is related to gender, to location of computer use, and to type of computer use can be expressed by the model. The general manifold model is displayed in Figure 1.

Insert Figure 1 about here

The edges joining the nodes in Figure 1 should not be thought of as projecting from access to the other nodes. Rather, these edges could be better replaced by at least two oppositely oriented arrows indicating a sense of mutual causality (Maruyama, 1965) and systematic feedback among nodes. For example, one's in- or out-of-school access experiences may help create or maintain stereotypes held about one's self or about others as computer users. In turn, one's stereotypes about computer use and users may condition one's access (computers are for "eggheads" or computers are too "unnatural," therefore, I do not wish to use them) and affect the quantity or quality of access.

The manifold model shown in Figure 1 can be considered not only in itself but in terms of how the patterns of interaction between its nodes are affected by embedding the model within a larger framework of different combinations of gender and type of use. In particular, three categories of computer use are

generally available to contemporary adolescents, at least in Canada. These categories are recreational use, nonrecreational home use, and in-school use. The general purpose of this study is to test the validity and predictive utility of the manifold model in the simultaneous analysis of a complex of interrelationships of five hypothesized variable clusters: (1) computer access, (2) personal and social attitudes and values with respect to computer use, (3) self-assessed competence and confidence with respect to computer use, (4) opinions of held stereotypes about computer use and users, and (5) perceptions of social issues and concerns accompanying widespread computer use, and to show how the behavior and even structure of this complex is affected by different combinations of use type (recreational, nonrecreational home, and school) and gender.

To study the topology and relational-link strengths of the manifold model the polyhedron was "unfolded" into a two-dimensional set of paths with the access node designated as a target node. The relationship between access and the other four variable sets in the model can be characterized by a set of ordered paths leading to or predicting access. The general manifold model was used as a base for the development of three distinct, fully recursive models for prediction of use of a computer for recreational purposes, for nonrecreational home use,

and for school use. The fit of each of these models to data obtained from a large sample of the target population of Canadian adolescents allows a test of a general hypothesis underlying the model--that different contexts affect the nature of computer access for adolescents. Each full model can then be reexpressed relative to gender, to reflect hypothesized interrelationships which may differ for males and females within each of the use categories. The fit of these gender-specific models can also be tested in order to examine the hypothesis that gender differences do characterize adolescent access to acomputers. These nine models--full models for recreational use, nonrecreational home use, and school use and reduced male and female models for each of the use types--were tested using data from a national Canadian survey. For clarity, the specifics and rationale for each of the nine models will be discussed separately in conjunction with the results of testing the fit of the model.

Method

Subjects

Subjects were 1,380 male and 1,428 female Grade 11 students representing all major urban areas in all ten Canadian provinces. The proportions of students from different geographic regions of Canada reflected the proportion of adolescents in each region according to the 1981 Canadian census, with a slight

overrepresentation of the Atlantic provinces. Students were intact Social Studies 11 classes in 123 different secondary schools (34 in Western Canada, 35 in Ontario, 37 in Quebec, and 17 in Atlantic Canada). The principal in each of the 123 schools was asked to designate a Grade 11 social studies class representative of the mix of students in the particular school. Social studies classes were chosen because the impact of technology on modern life is a topic frequently discussed in such courses. Thus, interest and expected agreement to participate were expected to be quite high. Enrollments also tend to cut across the various high school program streams to a greater extent than would be found in other subjects such as mathematics or science. Response rate was extremely good, as only of the schools asked to participate in the survey failed to do so.

Instrument

The survey instrument used in this study was a 130-item, six-part questionnaire, now in its fourth generation. It has been developed over a period of three years in three pilot projects preceding this study (Kass & Kieren, 1985, 1986). Items for its final form were scrutinized by sociologists at the Universities of Alberta and Laval, and by other researchers experienced with large-scale surveys of computer interaction (Kass, Kieren, Collis, & Therrien, 1987). The items were structurally validated through

the pilot studies of relationships among various access, value, stereotype, and social concern variables.

Each of the five nodes of the polyhedral manifold formed the basis of a subscale of a questionnaire. Detailed subscales dealing with access, self-assessment (confidence and competence), attitudes (personal values), held stereotypes, and social values and issues/concerns were included. Subscales and related measures of values and attitudes were devised for each category of recreational, task, and learning computer uses. Questions providing context data (e.g., computer ownership, computer course participation, academic, and demographic items) were also included. Table 1 presents the number of items comprising each component of the questionnaire and the alpha reliability of the component where appropriate. The 14-page questionnaire required approximately 40 minutes to complete; a copy is available on request.

Insert Table 1 about here

Specific Models and Results

Recreational Usage of Computers

Variables associated with recreational usage. It is reasonable to assume that prediction of a student's likelihood of

using a computer for recreational purposes is influenced by his or her general likelihood of using a computer at all--of having easy access to a computer in the home setting or at the homes of friends or at arcades. In addition, possessing some degree of general computer competence (or "literacy") is likely to be associated with the student's disposition to use a computer for fun and recreation. Certainly, the student's perception of his or her own competence at recreational usage as well as perception of the gender-appropriateness of recreational usage for him- or herself may influence the likelihood of using a computer for fun and recreation. Finally, the student's basic "pleasure level" or degree of enjoyment associated with computer game-playing and other recreation is likely to influence a decision to play or not to play. Figure 2 organizes these variables into a causal model for prediction of recreational computer use. This model is based on the general manifold model. In this model it is assumed that directional paths connect each variable to each variable to the right of it in the model.

Insert Figure 2 about here

Fully recursive model of recreational computer use. In a fully recursive model, every pair of variables associated with a

directional path is assumed to be related in a temporal fashion, with the variable from which a path emerges assumed to precede and influence the variable at the terminal point of the path (Biddle & Marlin, 1987). All of these assumptions must be theoretically justifiable (Anderson, 1987). In Figure 2, two variables are assumed to the the "starting points" of the cluster culminating at the variable describing frequency of recreational computer usage. These two variables, relating to parents' educational level and stereotypes associated with recreational computer use, are the "exogenous" variables in this model. They are not by any means assumed to be the only sources of influence on the other variables in the model; however, they are chosen as especially pertinent to the recreational access variable and their antecedents are simply taken as undefined. The influence of each variable on the variables to the right of it in the full model must be logically defended (Biddle & Marlin, 1987).

Exogenous variables. The first exogenous variable, a variable expressing parents' educational level, was obtained by a weighted combination of students' responses to two items from the survey instrument. These items asked the student to indicate the level of education each of his or her parents had completed. A student's score could range from 0 (neither parent having finished high school) to 8 (both parents having finished university). This

score was treated as an interval variable. The second exogenous variable, stereotypes associated with recreational computer use, were expressed by the sum of a student's responses to two variables from the survey instrument, both relating to the student's opinion about gender differences associated with recreational computer use. Scores were recoded so that a maximum score of 8 was associated with the most unstereotyped responses possible to these two items, and a minimum score of 0 was associated with the most stereotyped responses.

Endogenous variables. Access to a home computer was coded so that 0 corresponds to not having a home computer and 1 corresponds to having a home computer. Level of computer competence was obtained by calculating a tally of how much experience and expertise the student reported him- or herself to have with respect to using a word processor, using a printer and printing software, using a modem, doing programming, using a spreadsheet or database, and using the BASIC language. Scores on the competency variable could range from 0 (no experience in all of these categories) to 6 (some experience in all of the categories) and were treated as interval data.

Self-confidence about one's self as a recreational computer user was taken directly from a variable on the survey instrument where a score of 0 on a five-point scale was associated with a

self-ranking of unsure and a maximal score of 4 associated with confident in response to the question, "How do you feel about yourself as a recreational computer user?" Pleasure associated with recreational computer usage was obtained directly from responses to a variable asking the student to self-report extent of positive feeling about computer use for recreational purposes. Score ranged from 0 (associated with I do not like it at all) to 4 (with I like it a lot).

Finally, a variable expressing frequency of recreational usage was formed by a tally of responses to four variables, all relating to frequency of recreational computer usage at one's own home, at the home of friends, in arcades, and in school. The variable expressing frequency of recreational use could vary from 0 (no usage in any of these locations) to 8 (regular use in all these locations).

Fit of full model to predict recreational use of computers for male data. The full recursive model displayed in Figure 2 provides a moderately good fit for the males in this sample with respect to predicting their use of computers for recreational purposes, with a generalized multiple correlation coefficient of $R^2 = .586$. This 58.6% of the joint variation of the dependent variables explained by the model is significantly different from 0 ($W = 657.36$, significant using x^2 with 20 degrees of freedom

because there are 20 paths in the full model--see Specht, 1975).

Path analysis of the full recursive model yields predictions of the joint behaviour of all the endogenous variables in the model and generates prediction equations for each of these variables. Path coefficients of beta weights are obtained, representing direct and indirect effects. Because beta weights are standardized, they may be interpreted as indicating what portion of a standard deviation of the criterion will change with a change of one standard deviation of the predictor. An inspection of the path coefficients for the variables in the full model for the male data shows that having a home computer makes the largest contribution to the prediction of a male student's frequency of use of computers for recreational purposes (path coefficient = .326) followed by level of computer competency (.294), degree of pleasure the male student associates with recreational computer use (.238), and the self-confidence the male student brings to this use (.217). Parents' educational level has relatively little impact on the prediction of recreational use for males when using the full recursive model, and perceived stereotypes about boys being better than girls at using computer games make virtually no contribution (-.015).

Fit of full recursive model for female students. The full model provides a less effective fit for the female students in the

sample than it does for the males, with a generalized multiple correlation coefficient of R^2 = .405. Although only 40.5% of the joint variation in the set of endogenous or dependent variables is explained by the full model for females, this proportion is still significantly different from 0, W = 1166.16, evaluated as chi square with 20 degrees of freedom. The path coefficients for females are similar to those of the males, but with some notable exceptions. Having a home computer is more positively predictive of acquiring some level of computer competency for males (.442) than it is for females (.336), and is also more predictive of frequency of recreational usage of computers for males (.376) than it is for females (.224). Also, computer competency is more likely to be associated with higher levels of self-confidence with regard to recreational computer use for males (.222) than for females (.157). These differences in path coefficients are significant, $z = 4.97$, $p < .001$, for the first and second differences, and $z = 1.69$, $p < .05$, one-tailed, for the comparison between the relationship between computer competency and self-confidence in recreational computer use.

Reduced models for prediction of male and female recreational computer usage. Although the fully recursive model shown in Figure 2 can be supported as a logical basis for predicting recreational computer use, it is also reasonable to predict that

some of the paths in the model are of less potency than others for males while different paths may be reduced or enhanced in potency for females. Figures 3 and 4 show the predicted reduced models for prediction of males' and females' recreational computer usage. Labels of W, M, and S appear on the paths to express the hypothesized relative weights of the retained paths with regard to prediction (W = weak, M = moderate, S = strong). A number of paths have been deleted from the full model; these paths are hypothesized to have little effect on prediction when other variables are retained.

Insert Figures 3 and 4 about here

There are a number of differences in the hypothesized male and female models. A major difference is the exclusion of the computer competence variable from the male model. It is predicted that recreational usage of computers is so strongly pictured as "a thing males do" in the adolescent culture that a male student feels he can be an effective game player even if he has little computer competence or experience. Another major difference in the models is that the female model represents a more complicated set of influences preceding the female's decision to use a computer for recreation. It is hypothesized that the female will

be more influenced by her perception of her parents' attitudes about herself as a recreational computer user and will also be more sensitive to the impact of male-oriented stereotypes on her own self-confidence level than an adolescent male may be. It is further hypothesized that the female is more likely to want to feel computer competent before she risks computer usage for fun, and that her pleasure associated with recreational usage will be strongly influenced by her perceived competence and confidence. Males, it is hypothesized, do not particularly need this type of affective reinforcement, but find the process of recreational computer use much more straightforward; in fact, almost something expected of an adolescent male.

Testing the reduced models. In order for the reduced models to be supported as providing a reasonable fit for the data, male and female data were subjected to a series of regression analyses based on the gender-specific models. Beta coefficients and multiple R^2 values from these analyses were used in a subsequent series of path-analytic procedures. In addition, the fit of each gender-specific model for students for which it was intended was compared to the fit of the same model for students of the opposite gender, again using path-analytic procedures, to investigate the hypothesis that the gender-specific models reflect gender differences in systems of predictors of recreational computer use.

The specific hypotheses tested include:

1. The male model can be supported as providing a reasonably close fit for the fully recursive model for males.

2. The female model can be supported as providing a reasonably close fit for the fully recursive model for females.

3. The male model will fit the male data better than it fits the female data.

4. The female model will fit the female data better than it fits the male data.

And in summary,

5. Gender differences in the frequency of recreational computer usage are predicted by the differences in the male and female models.

Specht's test will be used to assess the fit of each pair of models.

Test of male and female reduced models for prediction of recreational usage. Figures 3 and 4 show the path coefficients for the male sample on the reduced male model and for the female sample on the reduced female model. In addition, path coefficients for the female data on the reduced male model and for the male data on the reduced female model are shown in parentheses. The residuals for the recreational access variable are .755 for male data on the male model, .843 for female data on

the male model, .756 for female data on the female model, and .844 for male data on the female model.

The path coefficients show five of the hypothesized paths in the male model are indeed associated with prediction in the model. The prediction that males' stereotypic perceptions of computer games being male-appropriate would only weakly influence males' actual recreational usage is supported. All three path coefficients emerging from the stereotype variable are small and contribute little to the prediction of other variables in the system. Parents' educational level influences recreational computer use less than what was predicted in the male model and stereotypes had a weaker impact on self-confidence for males than was predicted.

In order to assess the goodness of fit of the male model for males compared to the full recreational model, the Q statistic, $\frac{1 - R^2\text{Full}}{1 - R^2\text{Model}}$, was calculated and found to be equal to .673 (Specht, 1975). Q can vary between .000, showing no correspondence, or fit, in two models, to .999, showing the near-equivalence of two models. A Q of .673 shows a reasonable match when the more parsimonious male model is compared to the full recreational model. This goodness of fit can be evaluated for statistical significance; however the large sample size in this study

jeopardizes the possibility of retaining a model (Anderson, 1987) even with a Q as high as .99. Because of this sensitivity to sample size, x^2 is not recommended as a significance test for large models and samples such as these.

Another approach can be used to test the value of the male model as a predictor of frequency of recreational computer use for males: The model can be run using the female sample data and a Q value calculated to compare the fit of the male model for males and for females. The ratio obtained for this Q is $\frac{.615}{.722}$ or .852. The reduced male model explains 1 - .615 or 38.5% of the joint variation in the males' sample data, as compared to 1 - .722 or 27.8% of the joint variation in the females' sample data, and thus is a better fit for prediction of males' recreational computer usage than it is of females'.

The female model was evaluated in a similar manner as was the male model for predicting recreational computer usage. All but two of the paths hypothesized to be valuable as predictors of females' recreational computer usage are refelected in the moderately strong path coefficients for female data on the reduced female model. As was the case in the reduced male model, competency is a more important predictor of self-confidence for females than had been expected, and stereotypes were considerably

less involved in the prediction of other variables in the system than had been predicted. Finally, perceived competency affects self-confidence more than had been predicted for females.

A comparison of the fit, for females, of the female model with the full recreational model yielded a Q of $\frac{.595}{.648}$, or .918, indicating a very good fit of the more parsimonious recreation model for females. However, a comparison of the fit of the female model for females to its fit for males gives an unexpected result. The female model explains only 35% of the joint variation in the recreational usage system for females, but explains 52.5% of the joint variation for males. It is clear that alternate formations of the male model for predicting recreational computer usage should be considered.

Predicting Use of Home Computers for Nonrecreational Purposes

Certainly students are very familiar with recreational usage of computers. It is reasonably easy for most students to have some interaction with computer games, as game machines now are ubiquitous components of corner stores, ferries, and computer arcades. Games frequently are quick and easy to play, at least in a casual manner, so it was reasonable to assume in the models used to predict recreational access to computers that having a home computer was not essential for access to occur. However, a second

category of computer use--nonrecreational home use--cannot be assumed to be realistically available for students without any access to a home computer. The type of tasks associated with this category require time and often repeated periods of time. It is unlikely that many students routinely do word processing at a friend's house, for example, in the way they might casually play a game. Therefore, the full model we present for predicting use of a computer for nonrecreational home task purposes will only pertain to students with a computer in their homes. Examples of uses of a home computer for nonrecreational purposes include word processing, printing "something like posters, invitations, cards," "trying to learn something on a computer at home that is not part of homework," and doing homework. Homework is included as schools cannot yet require students to do homework at home on a computer because of the obvious difficulties this would create for the many students without home computers. Thus it can be assumed that use of a home computer to do homework is largely a voluntary decision by the student because presumably even computer science assignments could be done at school if the student really did not wish to make use of a home computer. Therefore, a variable expressed as a weighted combination of frequency of home usage in the above categories of uses was calculated for all students having home computers. This variable could range between 0 and 12

educational levels to make use of computers for task-type purposes in their offices or for "productivity tasks" at home. Therefore the model assumes that parents' educational level will have an influence on student task usage even when the sample already reflects the influence of parents' educational level by only including students with home computers. A variable reflecting parents' educational level was calculated in the same way as it was for the recreational models.

Nonrecreational task-type computer usage typically will involve reading of manuals and may involve considerable effort and persistence. Commercial productivity-oriented programs are not as simple to use as games may be and frequently require the user to be tolerant of and successful with self-directed efforts. Therefore it is reasonable to predict that a student's academic ability may predict his or her tendency to make voluntary use of home computers for nonrecreational usages since the same components of persistence, reading ability, and self-direction may also underlie academic success at school. Therefore, a variable relating to academic ability that requested the students to rate their grades compared to those of their classmates was included as one of the exogenous variables in the model. Although it is likely to be correlated with parents' educational level, for purposes of this model it is only assumed to be correlated with,

and was the criterion variable for the next set of models.

Exogenous variables in the full model for prediction of home nonrecreational computer usage. It is reasonable to predict that parents' educational level will be associated with student use of a home computer for nonrecreational purposes. Parents with higher educational levels may be more likely than parents with lower educational levels to make use of computers for task-type purposes in their offices or for "productivity tasks" at home. Therefore the model assumes that parents' educational level will have an influence on student task usage even when the sample already reflects the influence of parents' educational level by only including students with home computers. A variable reflecting parents' educational level was calculated in the same way as it was for the recreational models.

Nonrecreational task-type computer usage typically will involve reading of manuals and may involve considerable effort and persistence. Commercial productivity-oriented programs are not as simple to use as games may be and frequently require the user to be tolerant of and successful with self-directed efforts. Therefore it is reasonable to predict that a student's academic ability may predict his or her tendency to make voluntary use of home computers for nonrecreational usages since the same components of persistence, reading ability, and self-direction may

also underlie academic success at school. Therefore, a variable relating to academic ability that requested the students to rate their grades compared to those of their classmates was included as one of the exogenous variables in the model. Although it is likely to be correlated with parents' educational level, for purposes of this model it is only assumed to be correlated with, not caused by, parents' academic history. Other factors that may influence a student's academic performance are outside the scope of this model. The academic performance variable ranges from 0 to 4.

The stereotypes a student endorses about computer use and computer users are also hypothesized as exogenous variables in the full model to predict students' home nonrecreational use. If students perceive home nonrecreational use to be gender-typed or associate it with unattractive personality stereotypes they are less likely to choose to be identified with the usage themselves. Therefore, a variable was created as a weighted sum of responses to six statements on the survey instrument reflecting stereotypes about social, intellectual, and gender-related stereotypes about computer users. Each variable was recoded so that the higher the score on this variable the less stereotyped were the student's responses. This stereotype variable could range from 0 to 20.

Endogenous variables associated with the prediction of nonrecreational use of home computers. It is reasonable to predict that taking a computer-related course in school would expose the student to a variety of computer applications so that he or she would be more likely to use a home computer for similar activities or to do homework associated with the course. Therefore a variable, coded 0 if the student had not taken a computer course and 1 if he or she had, appears as a predictor of nonrecreational use of a home computer in the model. This computer course variable is classified as an endogenous variable in the model because of the assumption that parents' educational level, student's own academic performance, and stereotypes the student has about computer users will all influence the decision to take a computer course. Academic ability is included because the majority of computer science courses in secondary school require mathematics facility as a prerequisite and are typically perceived as challenging courses by students and teachers. Similarly it is reasonable to presume that the more "computer literate" the student is, the more likely the student will use a home computer for nonrecreational purposes.

A variable to represent computer competency was calculated in a similar way as occurred in the recreational model, with the addition of information from an item that directly assesses the

student's perception of his or her competency with nonrecreational home uses. The competency variable ranges from 0 to 12 and is assumed to be influenced by the student's having taken or not taken a computer course in school, and also by the exogenous variables in the model. Computer course experience and level of computer competency are also assumed to influence the student's perception of the value of doing tasks with a home computer; therefore an item from the survey instrument asking the student to describe his or her use of a home computer for tasks by selecting a point on a five-point scale with endpoints "Wasting time" and "Using time well" is included in the model. It is assumed that a student is more likely to use a home computer for nonrecreational purposes if the usage is perceived as valuable rather than frivolous (whereas the latter may well be the case with recreational usage). Again, the exogenous variables are also assumed to have an influence on the perception of the value of nonrecreational computer usage.

Finally, it is reasonable to assume that self-confidence and a general sense of enjoyment will influence a student's decision to use a home computer for nonrecreational purposes, although the enjoyment factor is likely to be considerably less salient than it is for recreational use. Self-confidence is assumed to precede "general liking" in the model. Figure 5 shows the full recursive

model for home nonrecreational use. For clarity, paths are not shown in the model; however they can be assumed to associate every variable as a predictor of every other variable located to the right of it in the diagram.

Insert Figure 5 about here

Goodness of fit of full model for nonrecreational home usage. Using the responses from the 583 males with home computers in the sample, multiple regression and path analysis were used to assess the fit of the full model for males. The model fits the male data well, with a generalized multiple regression coefficient of .874. Exactly the same generalized multiple regression coefficient was obtained with the data from the 417 female students with home computers. The specific prediction of nonrecreational home usage is slightly better for female students than for male students, with 33.1% of the variability in nonrecreational home usage explained for females compared to 32.1% explained for males.

Although the overall fit of the model is the same for females and males, the prediction equations developed from the direct and indirect effects in the models show gender differences in the patterns of strength of the predictors. (Coefficients can be directly compared within each equation because they are

standardized beta weights.) Table 2 compares the coefficients within each prediction equation.

Insert Table 2 about here

For both males and females level of computer competency is the strongest predictor of nonrecreational home usage of computers, followed by self-confidence and liking for male students and the same two variables in reversed order for female students. Stereotypes about computer users is the fourth strongest predictor for females, but only the seventh for males. For both males and females, academic performance was in fifth position, perceived value of the computer application in sixth place, and parents' educational level in last place. For females, surprisingly, parents' educational level has an inverse relationship to frequency of home nonrecreational use of computers. Thus other than the stronger relative importance of stereotypes on home use for females and the stronger relative importance of computer course experience for males the path coefficients in the two equations show very similar patterns.

Further inspection of path coefficients for the five equations defining the other endogenous variables in the models shows the same patterns of relative impact. Parents' educational

level has little predictive relationship with any of the endogenous variables while computer competency, self-confidence, and liking display a strong relationship in every equation in which they play a part. For males, the strongest individual predictors in the overall model are computer competency as a predictor of self-confidence (.600) and of frequency of home usage (.520), and self-confidence as a predictor of liking (.543). The same three pairs of associations show up most strongly for females, with path coefficients of .480, .483, and .541, respectively.

Reduced model to predict male's nonrecreational home use of computers. The full model for predicting nonrecreational home use of computers used eight variables as predictors. It is desirable that more parsimonious subsets of this model can be hypothesized so that they still provide good fits for the male and female data but at the same time might better highlight gender differences in the variables that influence nonrecreational home use for students having access to home computers. A rationale of the proposed reduced male model follows.

There is reason to predict that males' frequency of nonrecreational home computer use may be largely influenced by three sources: parents' educational level, perceived utility of the computer application, and general liking or disliking of using

a computer for nonrecreational purposes. Furthermore, it may be reasonable to predict that the other five variables in the model contribute only indirectly to the final prediction of usage for males through their influence on the three variables which directly influence the prediction. Academic ability, for example, will likely remain related to parents' educational level, stereotypes about computer users, and decision to take a computer course in school, but it is possible that, beyond this, males' sense of self-confidence, degree of computer competency, and of liking of nonrecreational computer use, as well as their level of perceived value of computer use, do not directly reflect academic achievement level. Figure 6 displays the reduced model for predicting nonrecreational home usage of computers for males, the hypothesized relative relevance of the retained paths, and the obtained path coefficients for the model when tested first with the male data and then with the female data.

Insert Figure 6 about here

Fit of the reduced male model for male and female students. The reduced male model explains 82% of the variability in frequency of nonrecreational home computer usage for males who have access to home computers. In comparison, the full model

explained 87.4% of the variability in males' usage. The comparison of these two proportions yields a Q value of .700, which suggests the reduced male model, with 18 fewer paths than the full model, does a reasonable job of fitting the data and also can facilitate interpretation, since so many fewer paths are involved.

Another way to assess the validity of the reduced male model is to compare its fit with the female data to its fit with the male data. Although the full models fit the male and female data equally well, Figure 6 revealed gender differences in the relative weights of path coefficients with regard to stereotypes and the effects of computer courses. As the reduced male model was developed specifically to reflect influences on males' nonrecreational home usage of computers, it is reasonable to expect it to fit the male data better than it fits the female data. However, this was not the case, as the male model predicted 81.9% of the variability in females' use of home computers for nonrecreational purposes (compared to 82% of the variability in males' usage).

When direct and indirect effects are combined, the equations generated for males and females on the male model are very similar, both in pattern and size. In each case, liking is the strongest predictor of nonrecreational home use. In addition,

relatively strong indirect effects were obtained for self-confidence (.355 and .352) and computer competence (.279 and .260) as predictors of nonrecreational home use even though direct effects for these variables as predictors of nonrecreational home use were not included in the male model. Perceived value of the computer use, which was hypothesized as being an important predictor in the reduced male model, did not emerge as having a strong predictive value. In addition, parents' educational level was not a predictor of nonrecreational home use.

Reduced model to predict females' nonrecreational uses of home computers. While it was predicted that the frequency of males' nonrecreational use of home computers would be a relatively straightforward reflection of how attractive and useful they perceive a computer application to be, it is reasonable to predict that for females the decision to use the computer may be influenced in a more complicated fashion. In particular, it is likely that females are more influenced by the stereotypes they hold about computer users and by their own levels of self-confidence than they are by more objective variables such as previous computer experience and perceived value of the computer application. As females are significantly less confident about themselves as computer users than are males, and as many of the stereotypes both males and females endorse imply that computer

users are males with somewhat unattractive personalities, the impact of these variables in the model may contribute strongly to females' levels of use of nonrecreational computer applications. The female subset of the full predictive model is given in Figure 7 along with the hypothesized relative strengths of the retained paths for females and the path coefficients obtained by testing the model with first the female, then the male data.

Insert Figure 7 about here

Fit of the female model for females compared to males. Using path analysis, the female model was found to explain 85.7% of the variance in females' frequency of nonrecreational uses of home computers. This compares to the 87.4% explained by the full model for females and shows that the reduced model with 13 fewer paths provides a very good fit for the female data, Q = .881. When the male data were tested against the female model, the female model explained 86.1% of the variability in males' nonrecreational home usage. Thus the female model fits the male data even better than it fits the female data, and in addition fits the male data better than did the male model. The path coefficients for the female model for both males and females were shown in Figure 7.

As before, a number of the predictions concerning the

relative strength of predictors in the reduced female model were not supported by the female data. Parents' educational level had only a weak influence on computer competency and perceived value of computers for females; the relationship was predicted to be a moderate one. Academic ability was predicted to be a strong component of computer course attendance; instead it was extremely weak. Stereotypes were predicted as having a strong influence on every endogenous variable in the model with the exception of perceived value; instead the effect was only weak or moderate. The influence of a school computer course on the females' self-assessment of competency at home computer tasks was severely underestimated, as was the importance of liking on frequency of nonrecreational home use. Self-confidence, however, emerged a strong predictor of both liking and frequency of use; these relationships were predicted by the reduced female model.

As can be seen in Figure 7, female and male path coefficients on the female model to predict nonrecreational home usage are generally similar, although females' paths from stereotypes to liking and nonrecreational usage are relatively stronger than males' and males' path from computer competency to nonrecreational usage is stronger than females'. For both females and males self-confidence (.477 and .509) and computer competency (.457 and

.522) are the strongest predictors of nonrecreational usage of home computers.

Summary of prediction of nonrecreational use of home computers. It appears the female model for nonrecreational usage of home computers provides a parsimonious and good fit for both the male and female data. This model shows self-confidence and degree of computer competency to be the major predictors of nonrecreational home use. Self-confidence in turn is most strongly influenced by computer competency, but less so for females (.463) than for males (.602). Computer competency with regard to home computer tasks is itself most strongly influenced by participation in a school computer course (.472 for females and .319 for males). The exogenous variables of parents' educational level, academic achievement, and stereotypes have relatively little effect on any of the variables, although stereotypes have a moderate association with self-confidence (.186, females; .201, males), liking (.200, females; .171, males), and frequency of nonrecreational access (.184, females; .140, males).

Predicting School Use of Computers

Full model for predicting school use of computers. It is reasonable to expect many of the same types of influences in school use of computers as occurred in the predictions of recreational and nonrecreational usage of computers. For example,

parents' educational level and having access to a home computer may be associated with a greater degree of computer familiarity and may also relate to the student's decision to study about computers in school as well as to the student's sense of self-confidence about computer use. Similarly stereotypes about computer users may serve either as facilitators or constraints on decisions to study about or otherwise use computers in school. Certainly the number of opportunities that arise for the student to use a computer as a tool in regular classroom settings such as science labs, mathematics classes, as a writing tool in language classes, or for information access and display in social studies classes is likely to contribute to the student's interest in computers as well as awareness of the value and application of computers in a number of different settings. Academic ability may also be related to school computer use if such use tends to be primarily the domain of students who take computer science courses or other courses with academic prerequisites.

Figure 8 shows the full model hypothesized to predict students' use of computers in schools. For clarity, paths associating every variable with every variable hypothesized to follow it in the model have not been drawn in; the full model predicts that the set of exogenous variables--parents' educational level, students' opportunity to use computers within regular

classes, students' own familiarity with computers through personal home access, students' academic achievement level, and stereotypes the students endorse about computers--all influence each of the six endogenous variables. The six endogenous variables are hypothesized to influence one another in the order shown in the model, with prediction of school usage the terminal variable in the model.

Insert Figure 8 about here

Fit of the full model to male and female data relating to use of school computers. The model provides an extremely good fit for the prediction of school use of computers for both males and females, with the generalized regression coefficient for males equal to .979 and for females, .976. Using the model, 62.8% of the variability in school use can be explained for males and 58.2% of the variability explained for females. Table 3 displays the path coefficients for the prediction of school use of computers using the full model. Because of the exceptionally good fit of the model for both the male and female data, the full effects for each of the six endogenous variables are included.

Insert Table 3 about here

It can be seen from Table 3 that both similarities and differences can be found in the influence of different variables on the prediction of males' and females' use of school computers. Contrary to prediction, parent educational level has little influence and what it does have is largely negative--the less educated the parents the more likely the student will use school computers. As predicted, academic ability has a weak positive relationship with the criterion variables, but unlike the prediction, this relationship is weak. Unlike expectations, stereotypes about computers contributed very little to prediction of the criterion variables in the model. Having a home computer is more definitely a predictor of school usage and other associated variables for males than it is for females. Taking a computer course is the strongest overall predictor of school use for both males and females. The affective variables in the model--perceived competence, perceived value, self-confidence, and liking--contribute strongly to the prediction of all variables following them in the model, with perceived value of computer use strongly predictive of self-confidence about computer use for both males and females. This relationship is difficult to interpret

and certainly was not predicted. Perceived value of computer use is more strongly related to liking for females than it is for males and an important predictor of overall frequency of school use for both genders. Self-confidence predicts liking more for females than it does for males but computer competency is a stronger predictor of variables following it in the model for males than it is for females. Liking has relatively little influence on school usage for either females or males.

Reduced model for prediction of males' school use of computers. While the full model presents a very good decomposition of the effects of different variables on the prediction of frequency of school use of computers, it is a highly complex model with 45 paths. A more parsimonious model with only 26 paths can be hypothesized for males. This reduced male model is shown in Figure 9 along with estimates of the relative strengths of the retained paths. The reduced male model reflects the assumption that males' school use of computers is most strongly influenced by their out-of-school experiences with computers as well as by their decision to participate in computer science courses at school. Labels indicating the hypothesized relative strengths of each of the paths for prediction of males' use of school computers are given on Figure 9 and repeated for convenience in Table 4 along with path coefficients for the model

obtained for both male and female data.

Insert Figure 9 about here

Insert Table 4 about here

Fit of reduced male model for prediction of school use of computers. The reduced male model, with 19 fewer paths than the full model, provides a good fit for the male data, $R^2 = .939$. Compared to the full model which explained 97.9% of the variability in school computer usage for males, the reduced male model loses relatively little in predictive power but gains considerably in terms of explanatory value for the model. The male model also fits the female data well, with a generalized regression coefficient of .914. However, a comparison of the fit of the male data compared to its fit for the female data can be expressed by a Q value of .709, supporting the hypothesis that the assumed predictors most influential for males are not the same or are not weighted the same as those that predict females' use of school computers. Females appear to differ from males most on the influence of a home computer on school use and on the impact of computer course experience and of perceived competency on

self-confidence. These relationships are stronger for males than they are for females. Hypothesized relative strengths were overestimated for males on the influence of parents' educational level on computer competency; the effect of a home computer on self-confidence and frequency of school use; the effect of academic ability on likelihood of taking a computer course, competency, and frequency of school use; and the impact of stereotypes on self-confidence and frequency of school use. There were also some estimates that were underestimated. These include the influence of subject use of computers on value and frequency of school use; of computer courses on perceived value and self-confidence; and the influence of competency on self-confidence.

Reduced model to predict females' use of school computers. While the male model to predict school usage of computers was based on the assumption that males are reasonably likely to make a straightforward transfer of their background and experience with computers into their likelihood of making use of school computers, it is reasonable to predict that females may mediate this transfer with a larger effect related to affective influences, such as stereotypes of computer users and personal self-confidence. There is evidence from research relating females' achievement and self-confidence in a variety of areas that suggests females are

more likely than males to base their sense of self-confidence not on their own performance but on preconceived opinions about their competency (Wollcat, Pedro, Becker, & Fennema, 1980). Thus the reduced model to predict females' use of school computers predicts less influence of experiential variables than the reduced male model and more influence of stereotypes and self-confidence. The female model with predicted relative strengths of path coefficients is shown in Figure 10. The reduced female model has 21 fewer paths than the full model for prediction of school usage of computers.

Insert Figure 10 about here

Fit of the reduced female model to predict school use of computers. The reduced female model provides a good fit for the female data with respect to predicting school use of computers, with a generalized regression coefficient of .900. This compares favourably to the coefficient of .976 obtained for the females on the full model. However, it is not as good a fit for the females as was the male reduced model (with R^2 = .914 for female data on the male model). The female model also provides a good fit for the male data and in fact, the male data fit the female model (R^2 = .917) better than the female data fit the female model.

However, the male model provides a better fit for the male data (R^2 = .939) than does the female model. Table 5 displays the obtained path coefficients for both females and males on the reduced female model to predict school use of computers along with the hypothesized relative strength of the paths for female students.

Insert Table 5 about here

Examination of Table 5 shows that 11 of the 24 predictions about the relative contribution of the various paths retained in the female model did indeed match their respective relative weights. However, the model overestimated the importance of academic ability and stereotypes on females' frequency of school use of computers and underestimated the impact of subject use and computer competency as well as the effect of having a home computer on perceived competency. As predicted, however, self-confidence is the major predictor of both liking and frequency of use of computers in schools. Male data fit the model in these same ways with only one notable exception--taking a computer course was a moderate predictor of school computer use for males but a suppressor of use for females, as shown by a path coefficient of -.313.

Summary of prediction of school use of computers. The so-called male model for prediction of school use of computers provides a very good fit for both the male and female data and facilitates interpretation of the frequency of this usage through its omission of 20 paths from the full recursive while losing only 4% in predictive power for males and 6.2% for females. This model emphasizes the impact of prior experiences with computers in the school and the perceived value of computer use as the variables most associated with the likelihood of school use of computers. Contrary to predictions, the model does not support more than weak predictive power for parents' educational level, students' academic level, and stereotypes associated with computer users. Finally, as predicted, having a home computer contributes substantially more to the likelihood of using a school computer for males than it does for females, although the relationships are at best moderate (.195 and .064).

Comparison of Models for Recreational, Home Use (Nonrecreational), and School Use of Computers

Table 6 summarizes the fits of the various hypothesized models for computer use.

Insert Table 6 about here

It can be seen from a survey of Table 6 that the hypothesized models for recreational usage of computers were much less effective in explaining the obtained data than were either the nonrecreational home use or school use models. The models are strongly supported in these latter two categories. The differential explanatory power of the three models supports a major premise of this study--that different networks of influences impinge upon students' decisions to use computers for recreational purposes, for nonrecreational purposes at home, and in school. Also, it can be seen that the predicted influences thought to be more important for females than for males actually fit the male data better than the female data for each of the three types of computer usage. This suggests that affective variables also are important influences of males' computer-use decisions.

Students' decisions to take computer courses at school are not explained by the exogenous variables in the models and perceived value of computer use is poorly explained by the variables preceding it in the various models. In contrast, self-confidence in school usage is particularly well explained by the full school model and liking of computer use is reasonably well explained in all of the nonrecreational and school use models.

Table 7 summarizes the influences of the predictor variables involved in the models.

Insert Table 7 about here

The unexpected finding in Table 7 is the overall lack of influence of parents' educational level and of stereotypes about computer users on frequency of usage in any of the three types of use. Having a home computer is a moderate predictor of likelihood of recreational use but means little in terms of frequency of school use. Self-confidence influences both home and school use and the likelihood of liking the use. Having taken a computer course is the strongest predictor of frequency of school use for both males and females when the full models are employed for prediction.

Summary

Overall, the models relate well to the data and support potentially important distinctions between predictors of computer usage with respect to recreational use, nonrecreational home use, and school use. These results indicate that it is inappropriate to make general statements about what influences students to use or reject computers; instead the context of usage must be considered. Also the results confirm the multivariate nature of

influences impinging upon the decision to use or not use computers. Finally, gender differences in the nature and intensity of these influences are supported by the data, but not to the predicted extent. The relative similarity in the patterns of influences on males' and females' frequencies of the different types of computer use suggests that the consistent gender differences in frequency of use that have been documented by this study are primarily explained by variations in the value of particular variables rather than by the influence of different sets of variables.

The overall goal of the study--to validate the manifold model as a conceptual organizer for the critical examination of the complicated multivariate system surrounding adolescents' decisions to make use of available computers--has been supported by the study. The manifold model, with its five nodes, has been shown to be a flexible and powerful device for the empirical investigation of various theoretical reformulations of the model based on different contexts of gender and usage type. Particular decisions about reduced versions of the model in terms of specific gender/use type contexts have been tested and suggest many directions for future research and reformulation. The degree of success that we have had with regard to the general goal of the study--to develop a model capable of conceptualizing and

supporting empirical investigators of the multidimensional system surrounding adolescents and computers--will depend on the utility of the manifold model for other researchers. We believe the utility is substantial.

References

Anderson, J. G. (1987). Structural equation models in the social and behavioral sciences: Model building. Child Development, 58(1), 49-64.

Biddle, B. J., & Marlin, M. M. (1987). Causality, confirmation, credulity, and structural equation modeling. Child Development, 58(1), 4-17.

Collis, B. (1984). The development of an instrument to measure attitudes of secondary school males and females towards computers. Unpublished doctoral dissertation, University of Victoria, Victoria, B.C.

Collis, B. (1985). Psychosocial implications of sex differences in attitudes towards computers. International Journal of Women's Studies, 8(3), 207-213.

Collis, B. (1987). Adolescent females and computers: Real and perceived barriers. In J. S. Gaskell & A. T. McLaren (Eds.), Women and education: A Canadian perspective (pp. 105-116). Calgary, AL: Detselig Enterprises, Ltd.

Cordell, A. J. (1985). The uneasy Eighties: The transition to an information society. Ottawa: Science Council of Canada.

Ellis, D., & Sayer, L. (1986). When I grow up: Career expectations and aspirations of Canadian schoolchildren. Ottawa: Minister of Labour, Government of Canada.

Ethington, C. A., & Woflfe, L. M. (1986). A structural model of mathematics achievement for men and women. American Educational Research Journal, 23(1), 65-75.

Hattie, J., & Fitzgerald, D. (1987). Sex differences in attitudes, achievement, and use of computers. Australian Journal of Education, 31(1), 3-26.

Heidegger, M. (1977). The question concerning technology. New York: Harper Row.

Ihde, D. (1978). Technics and praxis. Dordrecht: D. Reidel.

Kass, H., & Kieren, T. (1985). Micro-electronic technology and Canadian youth: A study of access, receptivity, and social impact (Interim Report under SSHRC Grant No. 499-84-0018). Edmonton, AB: University of Alberta.

Kass, H., & Kieren, T. (1986). Micro-electronic technology and Canadian youth: A study of access, receptivity, and social impact (Final Report under SSHRC Grant No. 499-84-0018). Edmonton, AB: University of Alberta.

Kass, H., Kieren, T. E., Collis, B., & Therrien, D. (1987). Computers and Canadian Youth Project (Final Report, January 1, 1986 - August 15, 1987, under SSHRC Grant No. 499-85-0021). Edmonton, AB: University of Alberta.

Lockheed, M. E., & Frankt, S. B. (1984). Sex equity: Increasing girls' use of computers. The Computing Teacher,

11(8), 16-18.

Maruyama, M. (1965). The second cybernetics: Deviation amplifying mutual causal processes. American Scientist, 51, 164-179.

Nora, S., & Minc, A. (1981). The computerization of society. Cambridge, MA: MIT Press.

Paisley, W. (1985). Children, new media and microcomputers: Continuities of research. In W. Paisley and M. Chen (Eds.), Children and microcomputers: Research on the newest medium. Beverly Hills, CA: Sage Publications.

Pask, G., & Curran, S. (1982). Microman: Computers and the evolution of consciousness. New York: Macmillan.

Schubert, J. G. (1984). Females and microcomputer use in school: Some insights into traditional patterns. Paper presented at the annual meeting of AERA, New Orleans, LA.

Shallis, M. (1984). The silicon idol: The micro revolution and its social implications. Oxford: Oxford University Press.

Shore, J. (1985). The Sachertorte algorithm and other antidotes to computer anxiety. New York: Viking Penguin.

Specht, D. A. (1975). On the evaluation of causal models. Social Science Research, 4, 113-133.

Turkle, S. (1984). The second self: Computers and the human spirit. New York: Simon and Schuster.

Wollcat, P. L., Pedro, J. D., Becker, A. D., & Fennema, E. (1980). Sex differences in high school students' causal attributions of performance in mathematics. Journal of Research in Mathematics Education, 11, 356-366.

Author Notes

This paper is based on work supported by Social Sciences and Humanities Research Council of Canada (SSHRC) Grants No. 499-89-1925, 499-84-0018, and 499-85-0011. The support of SSHRC is gratefully acknowledged. Information about the final report on the full study can be obtained from Dr. Heidi Kass, Department of Secondary Education, University of Alberta, Edmonton, Alberta, T6G 2G5. Send requests for reprints to the same address. A paper based on the manifold model and its application to the multidimensional production of access to computer use will be presented at the Annual Meeting of the American Educational Research Association, New Orleans, April 1988.

Table 1

Structure and Reliability of Study Questionnaire

Component	Number of Items	Alpha Reliability[a]
Demographic information	10	-
Objective questions relating to extent and frequency of computer uses for recreational, nonrecreational home, and school use	60	-
Held stereotypes about computer users	12	0.75
Social values		
Positive impact on society	14	0.76
Negative impact on society	10	0.73
Social concerns		
Felt personally	12	0.85
Expressed to friends	12	0.80

Note. [a]Based on 737 Grade 11 respondents in four provinces in Pilot 3 of the instrument validation process.

Table 2

Comparison of Predictors of Nonrecreational Use of Home Computers Using Full Model

Variable	Male[a]	Female[a]
Parents' Educational Level	.037[b]	-.135
Academic Performance	.142	.179
Stereotypes About Computer Users	.136	.193
Computer Course Experience	.200	.100
Computer Competency	.520	.483
Perceived Value of Computer Application	.138	.100
Self-Confidence	.484	.338
Liking	.374	.358

Note. [a]Students having access to a home computer; for males, N = 583; for females, N = 417. [b]Beta weights representing direct and indirect effects. Beta weights can be interpreted as describing what portion of one standard deviation of the criterion variable will change with a change of one standard deviation in the predictor variable.

Table 3

Full Model Path Coefficients for Variables Involved in the Prediction of School Use of Computers

Criterion Variables	Predictor Variables										
	Residual	Parent	Subject Use	Home Computer	Academic Ability	Stereo-types	Comp. Course	Comp. Competency	Value	Self-Conf.	Liking
					Males						
Computer Course	.970[a]	.039[b]	.015	.117	.080	.039					
Competency	.490	.036	.145	.628	.080	.061	.283				
Value of School Use	.738	-.021	.216	.135	.130	.051	.339	.316			
Self-Confidence	.264	-.010	.207	.168	.172	.052	.398	.377	.714		
Liking	.604	-.047	.126	.103	.227	.125	.330	.367	.360	.481	
Frequency of School Use	.372	-.022	.259	.154	.090	.066	.510	.358	.437	.395	.157

(Table continues)

Criterion Variables	Predictor Variables										
	Residual	Parent Subject Use	Home Computer	Academic Ability	Stereo-types	Comp. Course	Comp. Competency	Value	Self-Conf.	Liking	
					Females						
Computer Course	.987	-.064	.101	.006	-.007	.015					
Competency	.561	-.014	.095	.596	.063	.093	.192				
Value of School Use	.783	-.040	.222	.021	.073	.064	.345	.259			
Self-Confidence	.248	-.037	.233	.048	.100	.066	.363	.292	1.243		
Liking	.541	-.171	.182	.010	.173	.151	.300	.301	.475	.568	
Frequency of School Use	.418	-.137	.202	.012	.025	.034	.558	.270	.421	.368	.179

Note. [a]Percentage not explained by the model.

[b]Standardized beta weights for prediction of criterion variables.

Table 4

Path Coefficients for Male and Female Data on Hypothesized Reduced Male Model to Predict Use of School Computers

Criterion Variables	Predictor Variables											
	Residual	Parent Subject Use		Home Computer	Academic Ability	Stereo-types	Comp. Course	Comp. Competency		Value	Self-Conf.	Liking
					Males							
Computer Course	.972[a]	.038[b]		.122	.084							
Competency	.493	.034	.141	.813	.093		.178					
Value of School Use	.753	(.020)[c]	.205	(.201)	(.049)		.339	.260				
Self-Confidence	.673	.007	(.061)	.193	(.068)	.082	.610	.658				
Liking	.617	(.011)	(.046)	(.174)	(.053)	.042	.339	.323			.516	
Frequency of School Use	.409	(.022)	.229	.195	.041	.005	.509	(.178)		.380	(.127)	.246

(Table continues)

Criterion Variables	Predictor Variables											
	Residual	Parent	Subject Use	Home Computer	Academic Ability	Stereo-types	Comp. Course	Comp. Competency	Value	Self-Conf.	Liking	
					Females							
Computer Course	.997	-.057		.009	.002							
Competency	.569	-.008	.114	.600	.069		.207					
Value of School Use	.798	(-.019)	.183	(.114)	(.014)		.347	.186				
Self-Confidence	.773	.001	(.041)	.053	(.025)	.030	.379	.356				
Liking	.558	(-.009)	(.032)	(.073)	(.020)	.018	.314	.283		.609		
Frequency of School Use	.440	(-.030)	.114	.064	.026	.036	.563	(.132)	.320	(.157)	.257	

Note. [a]Percentage of variance not accounted for by the model.

[b]Standardized beta weights.

[c]Values in brackets are indirect effects not predicted by male model.

Letters relate to hypothesized relative strengths of the paths for males.

Table 5

Path Coefficients for Male and Female Data on Hypothesized Reduced Female Model to Predict Use of School Computers

Criterion Variables	Predictor Variables										
	Residual	Parent	Subject Use	Home Computer	Academic Ability	Stereo-types	Comp. Course	Comp. Competency	Value	Self-Conf.	Liking
					Females						
Computer Course	.999[a]				-.008	.010					
Competency	.574	.007[b]		.598	.071	.089	.217				
Value of School Use	.794	-.029	.163	(.110)	.077	(.019)	.312	.184			
Self-Confidence	.937		.241			.071					
Liking	.556		.180			.151				.644	
Frequency of School Use	.423	(-.004)	.159	(.014)	-.013	.020	-.313	(.023)	.126	.403	.192

(Table continues)

Criterion Variables	Predictor Variables											
	Residual	Parent	Subject Use	Home Computer	Academic Ability	Stereo-types	Comp. Course	Comp. Competency	Value	Self-Conf.	Liking	
					Males							
Computer Course	.988				.096	.049						
Competency	.510	.037		.621	.097	.060	.178					
Value of School Use	.744	-.044	.168	(.160)	.138	(.030)	.299	.257				
Self-Confidence	.924		.235			.147						
Liking	.631		.141			.146				.596		
Frequency of School Use	.380	(-.007)	.261	(.025)	.014	.079	.257	(.040)	.154	.451	.175	

Note. [a]Percentage of variance not accounted for by the model.

[b]Standardized beta weights.

[c]Values in brackets are indirect effects not predicted by the female model.

Letters relate to hypothesized relative strengths of the paths for females.

Table 6

Relative Power of Models as Predictors of Computer Use

Criterion Variables	Model: Recreational						Nonrecreational (Home)						School					
	Full		Male		Female		Full		Male		Female		Full		Male		Female	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Computer Course	NA	NA	NA	NA	NA	NA	1%[a]	2	1	1	1	1	3	1	3	1	1	1
Computer Competency	21	10	NA	NA	21	10	4	23	12	23	14	23	51	44	51	43	49	43
Value of Computer Use	NA	NA	NA	NA	NA	NA	3	9	2	5	2	5	26	22	25	20	25	21
Self-Confidence	10	7	6	5	9	5	44	30	40	25	40	27	74	75	33	23	8	6
Liking	11	9	9	7	9	7	39	43	39	42	38	41	40	46	38	41	27	44

(Table continues)

Criterion Variables	Model: Recreational						Nonrecreational (Home)						School					
	Full		Male		Female		Full		Male		Female		Full		Male		Female	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Frequency of Usage	31	19	24	16	24	16	55	54	43	43	55	53	63	58	59	56	62	58
Full Model	.586[b]	.405	.385	.278	.525	.352	.874	.874	.820	.819	.861	.857	.979	.976	.939	.414	.917	.900

Note. [a]Percent of variance explained.

[b]Generalized regression coefficients.

Table 7

Summary of Effects of Predictor Variables (Full Models)

Criterion Variables	Predictors									
	Parents' Educational Level	Students' Academic Ability	Stereotypes	Home Computer	Used in Classes	Computer Course	Competency	Perceived Value	Self-Confidence	Liking
Computer Course										
Nonrecreational home use										
Males	-.026	.053	.055							
Females	-.077	.010	-.099							
School										
M	.039	.080	.039	.117	.015					
F	-.064	-.007	.015	.006	.101					
Competency										
Recreation										
M	.153		.006	.442						
F	.045		.006	.336						

(Table continues)

Criterion Variables		Predictors									
		Parents' Educational Level	Students' Academic Ability	Stereotypes	Home Computer	Used in Classes	Computer Course	Competency	Perceived Value	Self-Confidence	Liking
Home											
	M	.021	.147	.124			.320				
	F	.007	.078	.103			.218				
School											
	M	.036	.088	.061	.628	.145	.283				
	F	-.014	.063	.093	.596	.095	.192				
Perceived Value											
Home											
	M	-.093	.088	.193			.019	.120			
	F	-.090	.050	.202			.069	.188			
School											
	M	-.021	.130	.051	.135	.216	.339	.316			
	F	-.040	.073	.064	.021	.222	.345	.259			

(Table continues)

Criterion Variables		Predictors								
		Parents' Educational Level	Students' Academic Ability	Stereotypes	Home Computer	Used in Classes	Computer Course	Competency	Perceived Value	Self-Confidence	Liking
Self-Confidence											
Recreation											
	M	.087		.017	.244			.222			
	F	.028		.080	.206			.157			
Home											
	M	.027	.195	.188			-.063	.600	.149		
	F	.134	.151	.192			.051	.480	.127		
School											
	M	-.010	.172	.052	.168	.207	.398	.377	.714		
	F	-.037	.100	.066	.048	.233	.363	.292	1.243		
Liking											
Recreation											
	M	.009		.008	.141			.194		.252	
	F	.013		.070	.093			.161		.207	

(Table continues)

Criterion Variables		Predictors									
		Parents' Educational Level	Students' Academic Ability	Stereotypes	Home Computer	Used in Classes	Computer Course	Competency	Perceived Value	Self-Confidence	Liking
Home											
	M	-.002	.098	.165			.119	.419	.152	.543	
	F	.112	.140	.201			.005	.387	.100	.541	
School											
	M	-.047	.227	.125	.103	.126	.330	.367	.360	.481	
	F	-.171	.173	.151	.010	.182	.300	.301	.475	.568	
Frequency of Use											
Recreation											
	M	.126		-.015	.376			.294		.217	.238
	F	.013		.070	.224			.218		.161	.279
Home											
	M	.037	.142	.136			.200	.520	.138	.484	.374
	F	.135	.179	.193			.100	.483	.100	.338	.358

(Table continues)

Criterion Variables		Predictors									
		Parents' Educational Level	Students' Academic Ability	Stereotypes	Home Computer	Used in Classes	Computer Course	Competency	Perceived Value	Self-Confidence	Liking
School											
	M	-.022	.090	.066	.154	.259	.510	.358	.437	.395	.157
	F	-.137	.025	.034	.012	.202	.558	.270	.421	.368	.179

Figure Captions

Figure 1. A manifold access model of adolescent-computer relationships.

Figure 2. Fully recursive model for prediction of use of a computer for recreational purposes.

Figure 3. Reduced model predicting males' recreational computer usage.

Figure 4. Reduced model predicting females' recreational computer usage.

Figure 5. Fully recursive model to predict nonrecreational use of home computers.

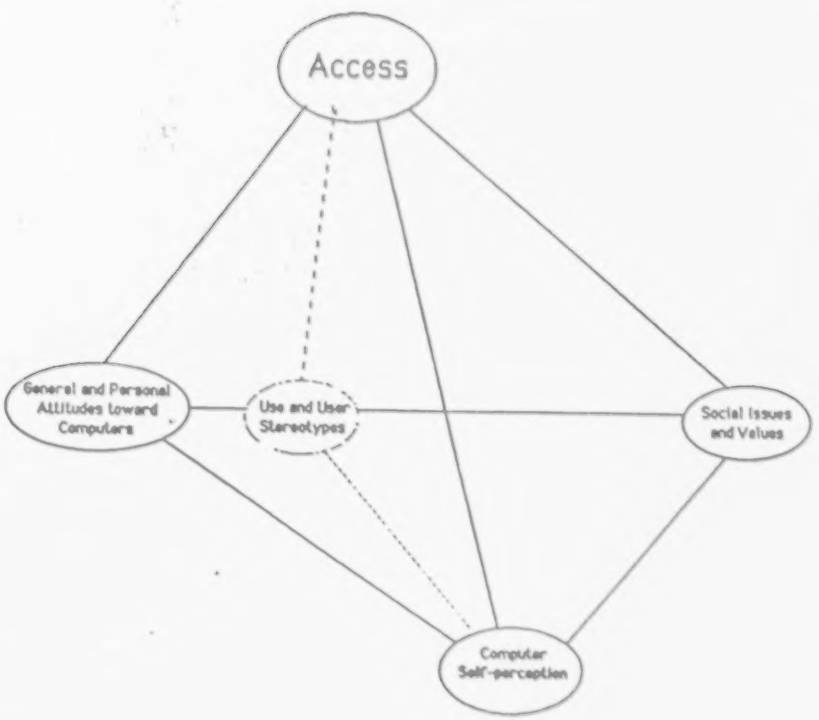
Figure 6. Hypothesized male model for prediction of nonrecreational use of home computers. Letters on paths represent predictions of relative influence of paths (W = weak, M = moderate, S = strong). Path coefficients for male and female data (female coefficients given in parenthesis) are associated with each path.

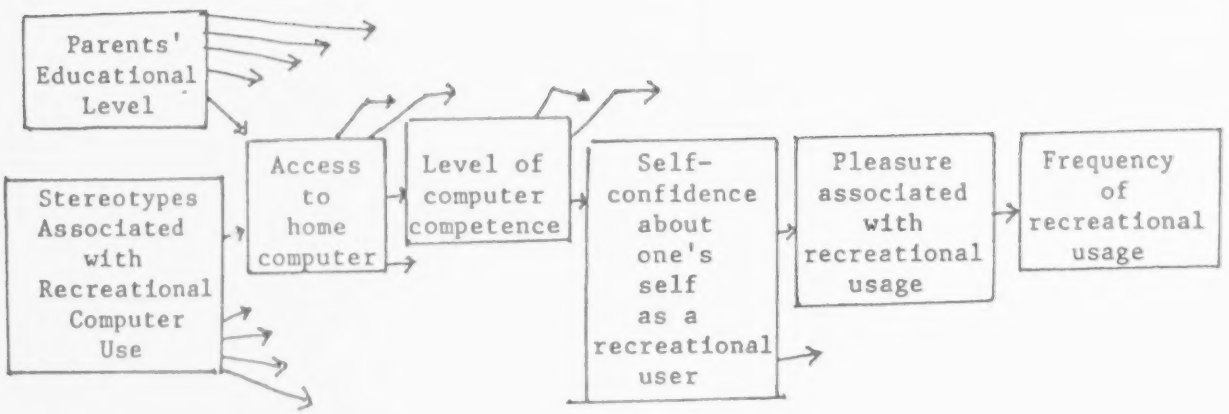
Figure 7. Hypothesized female model for prediction of nonrecreational use of home computers. Letters on paths represent predictions of relative influence of paths (W = weak, M = moderate, S = strong). Path coefficients for female and male data (with male coefficients given in parenthesis) are given on the paths.

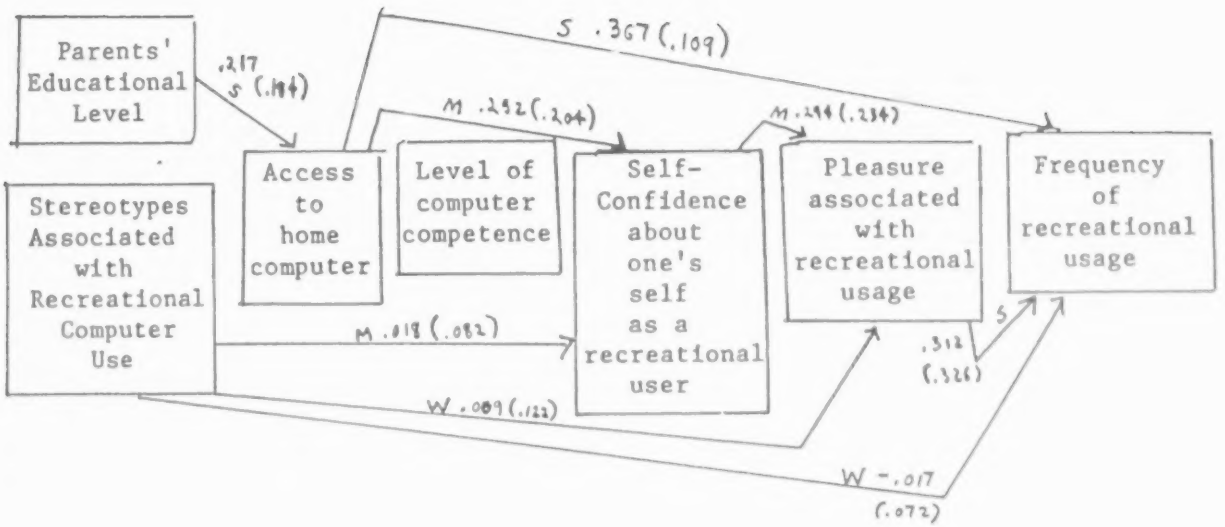
Figure 8. Full model for prediction of school use for computers.

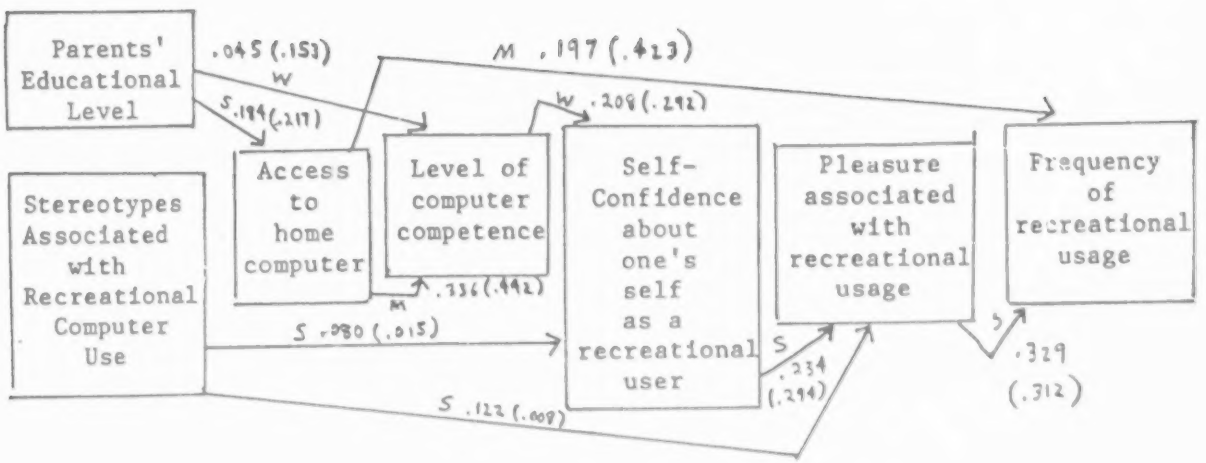
Figure 9. Hypothesized reduced model to predict males' use of computers at school. Labels indicate predicted relative influence of paths (W = weak, M = moderate, S = strong).

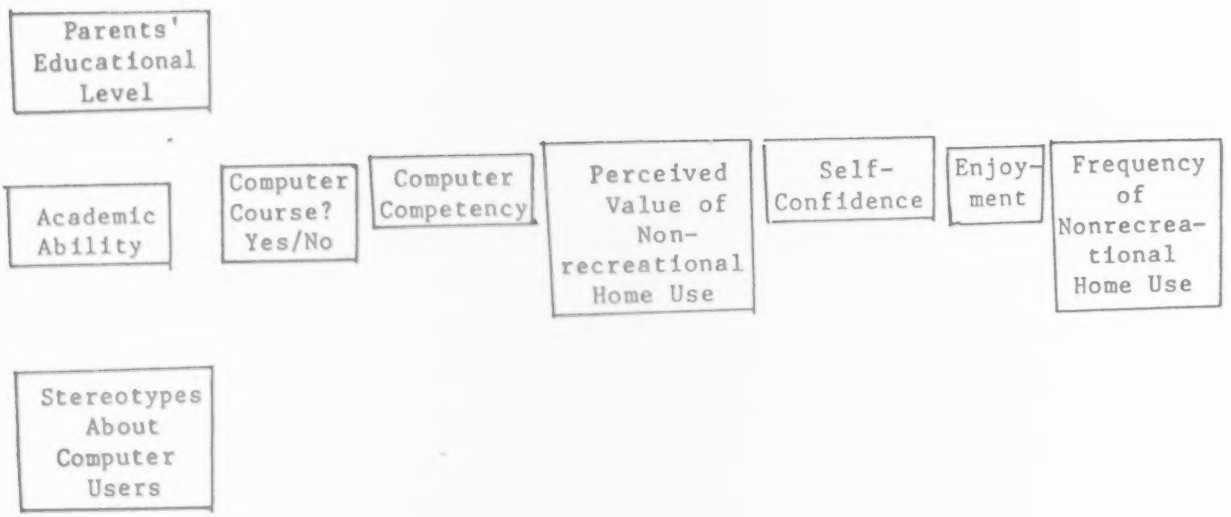
Figure 10. Hypothesized reduced model to predict females' use of school computers. Predicted relative strengths of paths for females given by labels W, M, and S (weak, moderate, strong).

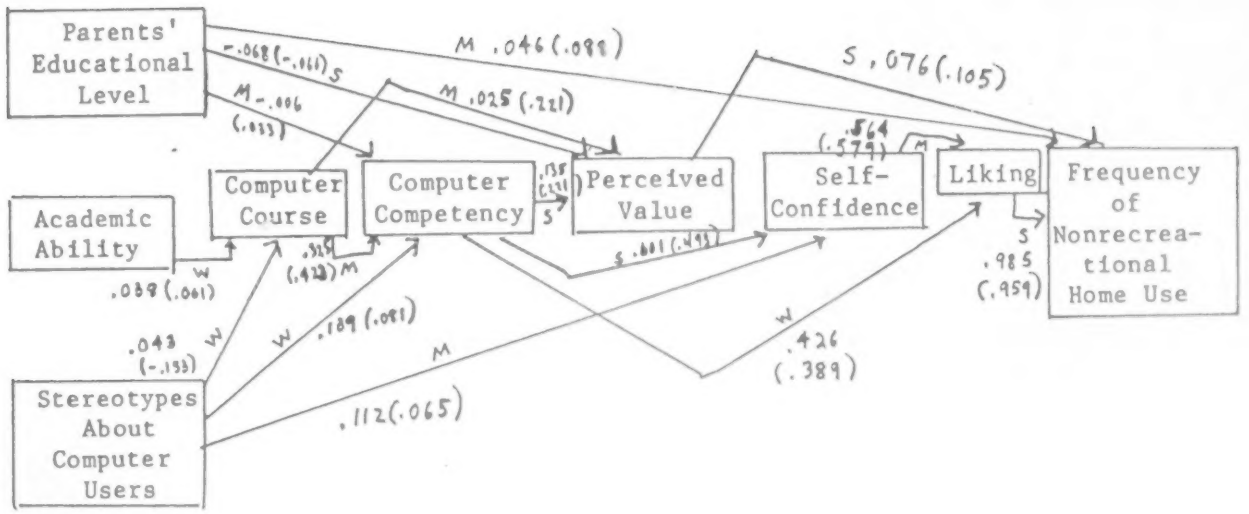

Access
General and Personal Attitudes toward Computers
Use and User Stereotypes
Social Issues and Values
Computer Self-perception

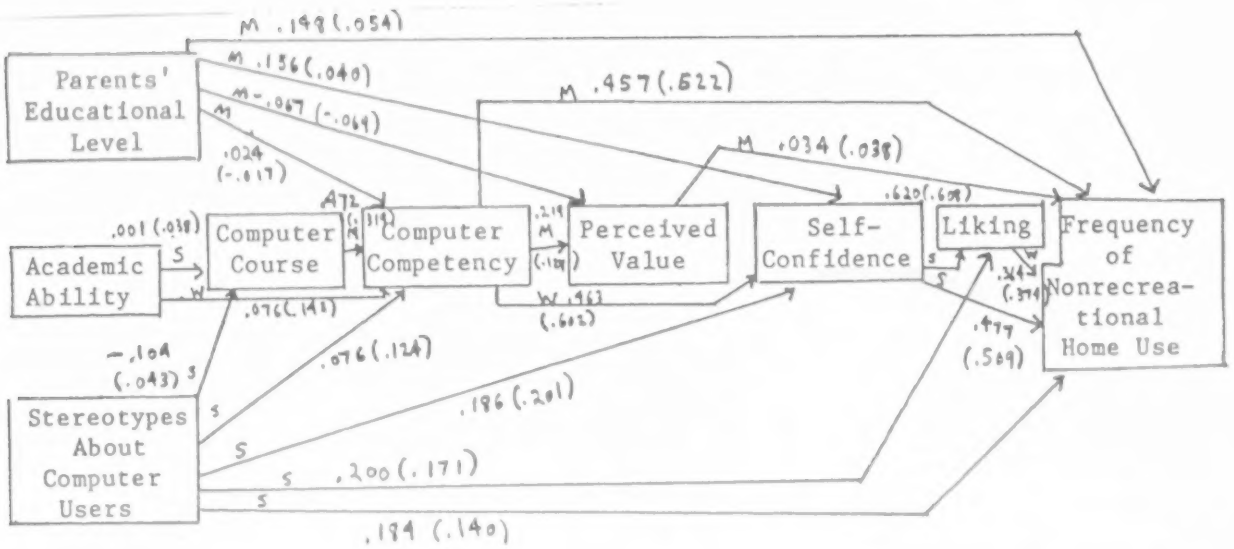

Parents' Educational Level
Stereotypes Associated with Recreational Computer Use
Access to home computer
Level of computer competence
Self-confidence about one's self as a recreational user
Pleasure associated with recreational usage
Frequency of recreational usage

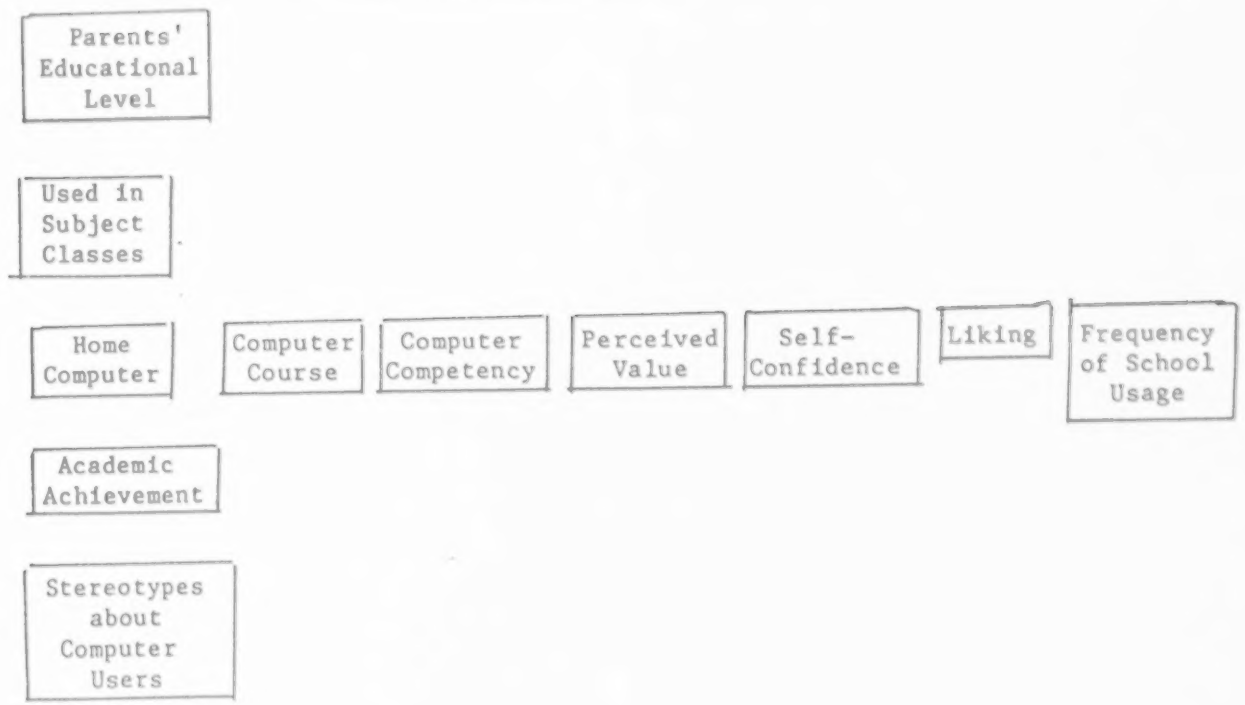

Parents' Educational Level
.217
S (.194)
S .367 (.109)
M .252 (.204)
M .294 (.234)
Access to home computer
Level of computer competence
Self-Confidence about one's self as a recreational user
Pleasure associated with recreational usage
Frequency of recreational usage
Stereotypes Associated with Recreational Computer Use
M .018 (.082)
.312
(.326)
S
W .009 (.122)
W -.017
(.072)

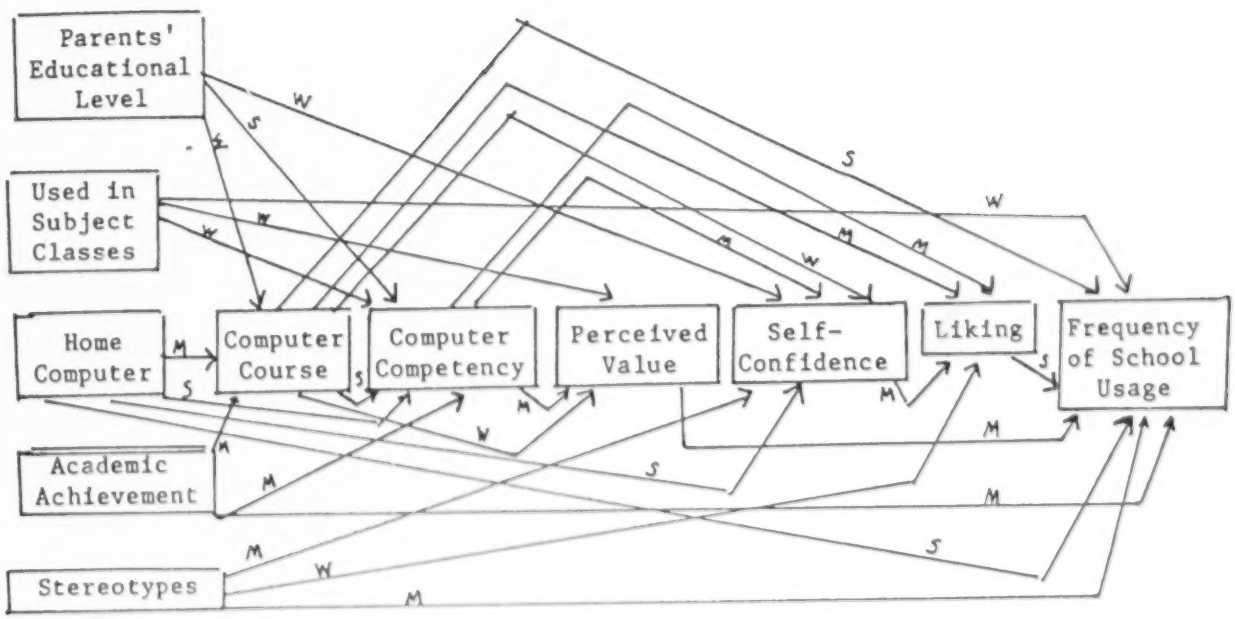

Parents' Educational Level
.045 (.153)
W
M .197 (.423)
S .199 (.217)
W .208 (.292)
Access to home computer
Level of computer competence
Self-Confidence about one's self as a recreational user
Pleasure associated with recreational usage
Frequency of recreational usage
Stereotypes Associated with Recreational Computer Use
M .736 (.492)
S .080 (.015)
S .234 (.294)
S .329 (.312)
S .122 (.008)

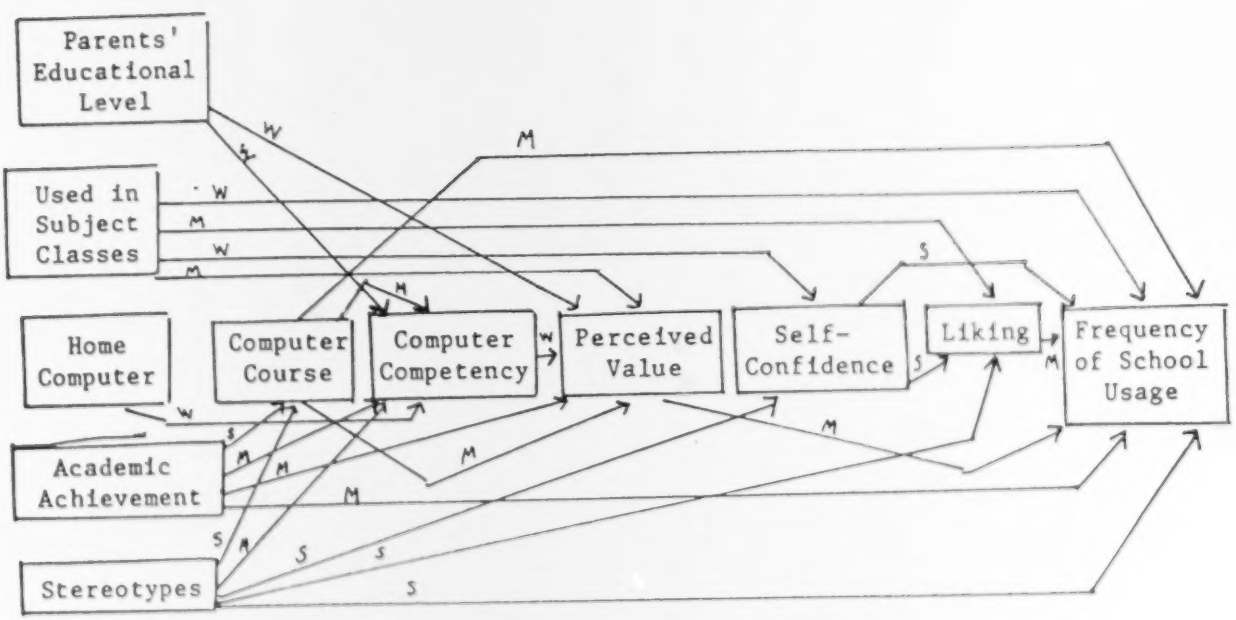

Parents' Educational Level
Academic Ability
Computer Course? Yes/No
Computer Competency
Perceived Value of Non-recreational Home Use
Self-Confidence
Enjoy-ment
Frequency of Nonrecrea-tional Home Use
Stereotypes About Computer Users


Parents' Educational Level
Academic Ability
Computer Course
Computer Competency
Perceived Value
Self-Confidence
Liking
Frequency of Nonrecreational Home Use
Stereotypes About Computer Users
-.068 (-.111) S
M .046 (.098)
S .076 (.105)
M -.006 (.033)
M .025 (.221)
.564 (.579) M
.135 (.131) S
.329 (.423) M
S .801 (.493)
S .985 (.959)
.038 (.061) W
.043 (-.133) W
W .189 (.091)
M .112 (.065)
W .426 (.389)


Parents' Educational Level
Academic Ability
Stereotypes About Computer Users
Computer Course
Computer Competency
Perceived Value
Self-Confidence
Liking
Frequency of Nonrecreational Home Use
M .198 (.054)
M .156 (.040)
M .457 (.622)
M -.067 (-.069)
M .034 (.038)
.024 (-.017)
.001 (.038)
.076 (.141)
.076 (.124)
-.104 (.043)
.196 (.201)
.200 (.171)
.184 (.140)
.620 (.678)
.477 (.509)
.344 (.374)
.963 (.602)


Parents' Educational Level
Used in Subject Classes
Home Computer
Computer Course
Computer Competency
Perceived Value
Self-Confidence
Liking
Frequency of School Usage
Academic Achievement
Stereotypes about Computer Users


Parents' Educational Level
Used in Subject Classes
Home Computer
Computer Course
Computer Competency
Perceived Value
Self-Confidence
Liking
Frequency of School Usage
Academic Achievement
Stereotypes
W
S
M


Parents' Educational Level
Used in Subject Classes
Home Computer
Computer Course
Computer Competency
Perceived Value
Self-Confidence
Liking
Frequency of School Usage
Academic Achievement
Stereotypes